1997

Cannibalization at the Pacific Fleet F/A-18 training squadrons

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THESIS

CANNIBALIZATION AT THE PACIFIC FLEET F/A-18 TRAINING SQUADRONS

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September, 1997

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE September 1997

3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE CANNIBALIZATIONS AT THE PACIFIC FLEET F/A-18 TRAINING SQUADRONS

5. FUNDING NUMBERS

6. AUTHOR(S) Williams, Racquel M., Lewis, Karon R.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Deputy Asst Cdr for Logistics, Mr Lawrence Milan, NAVAIRSYSCOM Hdqtrs, AIR3.0A, 47033 McLeod Rd. Patuxtent River, MD. 20670-1625

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS Cannibalization, Maintenance, Supply, Spare parts

15. NUMBER OF PAGES 89

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified

20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

CANNIBALIZATION AT THE PACIFIC FLEET F/A-18 TRAINING SQUADRONS

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MASTER OF SCIENCE IN MANAGEMENT

from the

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This thesis analyzes cannibalization as it affects the Pacific Fleet Navy and Marine Corps F/A-18 Fleet Replacement Squadrons. This thesis researches the supply/support posture of the F/A-18, identifies its shortcomings, analyzes the cannibalizations performed by the squadrons and determines the impact and usefulness of cannibalizations. An increase in cannibalizations increases component failure rates. Cannibalization doubles maintenance man-hours and depletes valuable resources. The data showed no clear linear relationship between cannibalizations and mission capable rate, flight hours completed, sorties completed or direct maintenance man-hours. There were many inconsistencies between different data sources. Cannibalizations should be kept to a minimum. More specific guidance is needed for cannibalization. A better tracking system is needed to capture all cannibalization data. Incentives should be incorporated to encourage truth and accuracy in reporting.

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I. INTRODUCTION

A. BACKGROUND

Cannibalization in Naval Aviation refers to the physical removal of serviceable parts or components from one aircraft for installation on another aircraft. Cannibalization is widely recognized among the aviation community as a source of wasted manpower, yet a necessity in meeting operational commitments. Operating activities are directed to carefully monitor and minimize the number of cannibalizations (canns) performed. This study will focus on the Navy and Marine Corps F/A-18 aircraft and the training squadrons in the Pacific Fleet. It will identify the causes of cannibalizations and determine their impact on manpower, readiness and asset reliability.

B. OBJECTIVES

This thesis has five major objectives regarding cannibalization.

1. To research the supply/support posture of the F/A-18 aircraft to determine the need for squadrons to cannibalize aircraft parts.

2. To compare the two squadrons studied and draw conclusions from the comparison.

3. To analyze the number and type of cannibalizations performed and discover the impact they have on man-hours, aircraft readiness, and resource availability.

4. To determine if cannibalization is a useful practice or if its effects are detrimental enough to warrant stricter controls.

5. To determine if significant shortages exist in the current methods of supply and logistics support for the F/A-18 aircraft that contribute to the need for cannibalizations.

C. RESEARCH QUESTION

The primary research question is: What is the impact of cannibalization?

D. SCOPE, LIMITATIONS AND ASSUMPTIONS

The research focuses on the F/A-18 aircraft. The F/A-18 aircraft has more unfilled/back-ordered initial outfitting documents than any other aircraft in the Navy and Marine Corps inventory. An initial outfitting document is the first time an allowance is authorized for material to support an aircraft/system. When a document is unfilled/back-ordered, the material is not available to meet the parts requirement. This is important because inadequate supply support can lead to increases in cannibalization. The research is also limited to the two Pacific Fleet training squadrons for the F/A-18. They are VFA-125 at NAS Lemoore and VMFAT-101 at MCAS El Toro. Training squadrons have historically had higher cannibalization rates than operational squadrons because they are often directed by the Type Commander(TYCOM) or Wing to cannibalize items for squadrons that

are deploying.

Due to the unavailability of scheduled flight hour data from VFA-125, the study was unable to examine the relationship between cannibalization and flight hour completion. The specific cost of repairables affected could not be determined, to show how cannibalization impacted the cost of repairables in the system.

Using the F/A-18 as the example for the rest of the aircraft in the Navy and Marine Corps inventory, the assumption is made that the actions of the two squadrons chosen are a worst case scenario as compared to the rest of the fleet. There are several different sources of data. Only one data source was used throughout a specific analysis method. The data source is cited before use.

E. METHODOLOGY

Data was organized separately for the two squadrons, covering the period from January 1994 to December 1996. Time series, correlation and regression analysis was performed on the different sets of data.

The following sources of data were used:

1. Aviation 3M data. The Naval Aviation Maintenance Office (NAMO) retains complete records on all aircraft. This data was the primary source for the flight hour data.

2. BD/QQQ data. Data was obtained from Commander Naval Air Force Pacific (COMNAVAIRPAC) and Naval Inventory Control

Point(NAVICP).

3. Interviews. Personal interviews were held with members of the squadrons, supply department and comptroller's office.

F. ORGANIZATION

Chapter II of this thesis provides both background on the F/A-18, including its supply/support posture, and insight into why the F/A-18 was chosen for the study. It also describes some the unique characteristics of the two squadrons. Chapter III is an overview of the supply and maintenance procedures for the Navy and Marine Corps. The basic principles of the supply system will be described along with the policies and procedures for cannibalization. Chapter IV describes the methodology used in gathering information and analyzing data. Chapter V presents the data collected. It contains graphs and tables summarizing the data. Chapter VI is the analyzes the data collected, including observations and interpretations. Chapter VII reports the conclusions and recommendations of the research.

II. LITERATURE REVIEW/BACKGROUND

A. LITERATURE REVIEW

To fully understand the rationale and necessity of cannibalization actions, the authors performed extensive background research using the following publications: OPNAVINST 4790 (series), several theses dealing with cannibalization, articles and micro fiche dealing with cannibalization, Jane's "All The World's Aircraft", the Internet, a Naval Inventory Control Point (NAVICP) presentation explaining the budget process, and a NAVAIR presentation explaining the supportability and readiness assessment of F/A-18 Fleet Readiness Squadrons.

B. BACKGROUND

In a search for a fighter and attack capable aircraft, the Navy accepted a combination of F-18 fighter and A-18 attack aircraft, designated the F/A-18 Hornet. It was manufactured by McDonnell Douglas with Northrop as a subcontractor. While this strike fighter aircraft has been flying since 1978, support for the aircraft is still lacking, specifically spares.

There are numerous versions of the F/A-18. The models progress from A through F. There are several different lots within each model, causing further variation. The various improvements to the F/A-18 allow the aircraft to grow with technology. However, the numerous type/model/series combined with the complex avionics, sophisticated design features and

advanced systems on each aircraft complicate its supply support system.

1. Why Study the F/A-18?

The F/A-18 aircraft has the most models, series, and configurations of any aircraft in the Naval Aviation inventory. As mentioned above, this makes the aircraft one of the most difficult and expensive aircraft to support. As new aircraft are designed and improved, support issues become more and more challenging. Engineers have designed many new components that allow interchangeability from one lot to another. Unfortunately, interchangeability mainly works from a lower to a higher lot aircraft. This creates spare shortages for lower lot aircraft. The tendency is to buy newer, more advanced equipment rather than expend scarce funds on older items, even though lower lot aircraft may still need the equipment. This fact becomes apparent by reviewing the current outstanding initial outfitting documents in NAVICP's outstanding document file.

2. Support System

Upon evaluation and analysis of the entire outstanding initial outfitting documents file, the following tables were created. Table 1 illustrates the grand totals of all documents outstanding for all ships, Naval Air Stations and Marine Aviation Logistics squadrons as of March 1997, for the indicated FY. It identifies the site with the highest ranges(variety of

requisitions) and depths(total number of requisitions) of outstanding requirements for that FY. Additionally, it identifies the percentage of F/A-18 aircraft supported at the site.

FY	Site (Range)	Site (Depth)	% of Total Range/Depth	% baseload = F/A-18
92	Sigonella	Sigonella	100% 100%	0% 0%
93	MALS-31	MALS-31	67% 50%	100% 100%
94	NASNI	NASNI	16% 27%	0% 0%
95	Cecil Field	Mayport	10% 19%	75.7% 0%
96	NASNI	NASNI	12% 11%	0% 0%
97	Eisenhower	Eisenhower	37% 39%	48.7% 48.7%

Table 1. Unfilled BD/QQQ Documents (Range/Depth)

Table 2 reviews the same period, listing the sites with the greatest extended money value(EMV) of unfilled initial outfitting requirements for the indicated FY.

FY	Site	% Total EMV	% Baseload = F/A-18
92	Sigonella	100%	0%
93	NASNI	30%	0%
	China Lake	21%	53.3%
94	NASNI	15%	0%
	Mayport	15%	0%
95	MALS-31	29%	100%
	MALS-11	25%	87.3%
96	Norfolk	12%	0%
	Carl Vinson	11%	28.6%
97	John Stennis	27%	42.9%
	Eisenhower	22%	48.7%

Table 2. Unfilled BD/QQQ Documents (EMV)

The above tables identify the most significant initial outfitting shortages throughout the Pacific and Atlantic fleets. A supply department's ability to support its squadrons is based primarily upon the stock posture of its warehouse. The previous tables indicate shortages dating back to 1992. There are initial outfitting documents dating back to the late 1980's; for the purpose of this research, only the last 5 years were examined.

Upon review of the tables, it appears that the shortages alternate between the Pacific and Atlantic Fleets. While this method of alternating deficiencies benefits the applicable sites,

it also masks the problem. By alternating shortages from one year to the next, the fleet perceives that they are getting "well" every other year. In reality, the shortage will recur the following year. This is shown in Table 1 by the alternation between Pacific and Atlantic activities, but also by the alternation between F/A-18 sites and non-F/A-18 sites, as identified in the last column. It is important to understand this process in order to evaluate potential impacts in other areas.

3. Supply Support for the F/A-18

While the above tables identify the F/A-18 site deficiencies versus the entire fleet, a more comprehensive analysis can be done by breaking down the data into two categories: NASs and MALS. A more detailed picture of the deficiencies within the F/A-18 community versus other aircraft at similar land based sites is provided in Tables 3 & 4.

Tables 3 and 4 illustrate the alternation between the F/A-18 and non-F/A-18 for range and depth deficiencies. Once again, this masks the deficiencies, and appears to continue. The Marine sites with F/A-18s have significantly more shortages than Marine sites with other aircraft.

FY	Site (Range)	Site (Depth)	% of NAS range/depth	% Baseload = F/A-18
92	Sigonella	Sigonella	100% 100%	0% 0%
93	Cecil Field	Atlanta	15% 22%	75.7% 35.3%
94	NASNI	NASNI	23% 35%	0% 0%
95	Cecil Field	Mayport	17% 30%	75.7% 0%
96	NASNI	NASNI	20% 18%	0% 0%
97	Lemoore	Lemoore	43% 39%	100% 100%

Table 3. NASs

FY	Site (Range)	Site (Depth)	% of MALS range/depth	% Baseload = F/A-18
92	None			
93	MALS-31	MALS-31	67% 50%	100% 100%
94	MALS-31	MALS-31	26% 38%	100% 100%
95	MALS-11	MALS-16	22% 24%	87.2% 0%
96	MALS-11	MALS-11	28% 35%	87.2% 87.2%
97	MALS-14	MALS-14	72% 67%	0% 0%

Table 4. MALS

4. BD/QQQ Status

While the outstanding initial outfitting documents can help determine of current shortages, they are not all inclusive. The initial outfitting documents are identified by a 'QZ' fund code on the requisition, and the status given to an unfilled QZ document is BD/QQQ. This status identifies this type of document. It also provides a method for calculating the number of QZ documents and evaluating item managers in their ability to fill their requirements.

5. Reasons for Cannibalization

Comparing the major degraders for the F/A-18 with the historical list of top five cannibalizations (per month) for a period of two years, a 33% commonality was found between items with supply shortages and high cannibalization rates. This commonality suggests that asset shortages leads to increased cannibalizations.

While VMFAT-101 has increasing cannibalization trends; VFAT-125's trend is decreasing. These trends may be explained by either the differences in cannibalization procedures and policies within each squadron or the personalities within the maintenance departments during the observed times. It is important to point out that VMFAT-101 faces higher (slower) supply response times, meaning that it takes longer for them to receive a part from supply. Since supply shortages are the most common cause for

cannibalizations, it is reasonable to assume that slow delivery time is partially responsible for the increase in cannibalizations.

Even if assets are available at the local supply department, the time required to deliver the part is often unacceptable to the squadron. The goal of the supply department is to deliver high priority parts within one hour of order placement. Aircraft are usually used for multiple sorties throughout the day. The turnaround time for the aircraft is often less than one hour. Parts are cannibalized even when the asset is available and being delivered within the prescribed time.

Personalities of the maintenance department managers play a large role in the tendency towards cannibalization. Some maintenance managers are quicker than others to resort to cannibalizing parts. All squadrons are under guidance to minimize cannibalizations. There is not a set goal, and thus interpretations vary considerably.

III. OVERVIEW OF SUPPLY AND MAINTENANCE PROCEDURES

A. SUPPLY PROCESS

1. Buy-in/buy-out process

The most common explanation for cannibalization is lack of supply assets. There are many reasons why supply assets are lacking. The best way to understand these reasons is to understand the initial and follow on procurement processes. Once a system is procured, spare assets are also procured to support the system when parts fail. The requirements determination is based on the flight hours projected in the Weapons System Planning Document (WSPD), baseload document, engineering estimated failure rates, avionics install plan, maintenance repair level, the flying hour program and component costs.

Each site's requirements are based on a specific number of days support and wartime/peacetime hours. The type of site and its location determine the range and depth of assets procured for that site. An aircraft carrier or Marine Air Group (MAG) is outfitted for 90 days support using wartime hours; while an overseas Naval Air Station (OCONUS) is outfitted for 60 days support using wartime hours; and a CONUS Naval Air Station (NAS) is outfitted for 30 days support using peacetime hours.

Retail site outfittings, Fleet Industrial Supply Centers (FISCs), are determined differently than squadron supply departments. The weapons system baseload is one of the

supporting data sources. Also included are the procurement quantities, delivery schedules, site activations or buildups, deployment schedules, and supply support scenarios. The retail sites need to stock the proper supplies to fill the order/reorder requirements of the NASs/MALS.

Another important consideration is the system cost sheets. The cost sheets contain the aircraft flyaway cost and the system/component costs. If an asset cost is extremely high, it is likely that the depth and possibly the range of allowances for that asset will be very low. Since the F/A-18 is one of the more expensive aircraft in the inventory, understanding cost constraints in allowancing methodologies is important.

The NAS/MALS is not only outfitted with spare parts support, but also has requirements for test bench installations (TBIs), maintenance assist modules (MAMs), and complete engine repair (CER). Each of these requirements will have additional parts requirements. TBIs need weapons replacement assemblies (WRAs) for the test bench, and often additional requirements based on engineering specifications. MAMs need to have SRAs for fault isolation. Finally, CER reduces spare engine TAT/investment, but it requires major engine repair capability at individual sites. This is a costly investment.

In addition to the NAS/MAG/CV support requirements addressed earlier, additional support packages are built into the user's support allowances. Marines use a Contingency Support Package

(CSP) which is built for 90 days using wartime hours. It is an I-level support package equal to a CV/MAG computation and based on aircraft numbers identified in baseloads. This package supports deployment requirements where the aircraft will need support but will be geographically separated from their home base.

The Navy uses a Supplemental Aviation Spares Support (SASS) package. This is an O-level support package, and is built to specified support levels for a pre-determined number of aircraft. This package is also used to support the aircraft while they are away from their home base. SASS packages must maintain high range and depth levels for these assets to effectively support the squadrons while on deployment. These assets are above and beyond the core support required for the aircraft. These assets are normally used to support home guard aircraft on deployment. An FRS will not normally have access to SASS material, limiting its access to spares support.

In addition to the known requirements, there are often unanticipated upgrade and configuration changes. This creates special support requirements. This is not baseload driven, and can vary dramatically from program to program. Further considerations must be given to common avionics systems, modifications, and support equipment. Since deploying squadrons normally take the same types/lots of aircraft, the FRSs usually have the largest variation of type/model/series aircraft to

support.

The bottom line is that there are many parts requirements and limited resources to obtain them. There are several considerations in obligating funds for material. Even after making the obligation, funding deficiencies are still an issue.

2. How Funding Deficiencies are Handled

When a system is procured and requirements determined, only 85% of the total financial requirement is funded. Before the parts are even ordered, the program is already 15% short of its requirements. The item managers at NAVICP-Philadelphia are directed to establish contracts for all (100%) system requirements knowing that there 15% funding shortfall. This initial phase of procurement is called the buy-in phase. During this time, item managers research and develop the contracts necessary for needed material. This phase can last up to two years.

The next phase is the buy-out phase. In this phase, contractors develop capabilities to obtain the needed assets under contract or look for sub-contractors to meet the contract terms. Contractors are normally given up to two years to begin filling the requirements. The entire buy-in/buy-out process, from the initial customer requirement until it is filled, can take up to four years. The duration of the buy-in/buy-out phase may leave deficiencies in aircraft support, which creates an

environment where cannibalization is the most viable alternative.

NAVICP budgeteers operate knowing that there will be a shortfall of 15%, and plan on finding a way to fill the deficit prior to incurring financial obligation. To do this, they must re-allocate or shift funds as requirements become available. This process is referred to as churn.

3. Effects of Churn

Since funds are not obligated until the asset is received/issued, back-ordered assets are frequently canceled and the funding reallocated to pay for available material. This type of churn creates a continuous funding deficit that is merely shifted from one contract to another. This creates material shortfalls. The initial funding shortfalls ultimately lead to asset shortages. Until this practice is changed, the supply system can not support all material requirements.

B. CANNIBALIZATION PRACTICES AND POLICIES

Work-arounds to material deficiencies are created to continue flying the required missions and keeping mission capability rates at acceptable levels. Cannibalizations are an often utilized work-around. If there is a requirement for an asset, and the material is not readily available through the local supply department, the squadron will often consider cannibalizing the asset from an already down aircraft, shifting the requirement to that aircraft. This will keep the same number

of requirements, but will allow them to have more FMC/MC aircraft. While it gives the squadron a higher full mission/mission capability rate, cannibalizations can dilute the sense of urgency associated with procuring the component because the squadron maintains a higher mission capability rate; it is then out of the spotlight. Cannibalization, at a minimum, doubles the maintenance man-hours for the single requirement. The maintainer is also faced with the possibility of breaking the working component through the maintenance action, thereby increasing the parts requirement. Constant cannibalization of a single aircraft often degrades an aircraft to a Special Interest Aircraft (SPINTAC). SPINTAC aircraft are those that have not flown for 60 consecutive days.

In the late 1970's, the Chief of Naval Operations recognized the wasted man-hours involved in cannibalization. He directed all aircraft squadrons to reduce cannibalization. Cannibalization has remained an important issue in aircraft maintenance. OPNAVINST 4790.2F states that "cannibalization with few exceptions, is a manifestation of a logistic or maintenance support system failure." It further states that cannibalization reduces morale and worsens NMCS/PMCS situations. Commands are directed to keep cannibalizations to a minimum. Measurement criteria for effective cannibalization include cannibalizations per 100 flight hours and cannibalization maintenance man-hours per month.

Like all maintenance actions, cannibalizations are documented on a maintenance action form(MAF). This documentation helps monitor cannibalization actions. Cannibalization actions are identified by their malfunction code. At the organizational level, the Maintenance Material control Officer(MMCO) establishes procedures for controlling cannibalization. (OPNAVINST 4790.2F) There are some systems which require special instructions for cannibalization. Egress system components cannibalization is specifically directed to be minimized. Cannibalization of egress systems exposes maintenance personnel to unnecessarily hazardous repair procedures. Logbook entries are required when removing this type of equipment, as well as aircraft engines. Reducing cannibalizations will reduce the possibility of administrative error.

Both squadrons in this study have published their own Maintenance Instructions (MI) for cannibalizations. For each squadron, the instructions amplify the instructions written by their wing commanders and the guidance provided in OPNAVINST 4790.2F. Each squadron has provided their own view on handling cannibalization.

The stated goals of VFA-125 in reducing cannibalization reflect the broader objectives of asset management and system discipline. They are:

1. Ensuring maintenance personnel are properly trained and proficient.

2. Rigid adherence to proper troubleshooting techniques and utilization of prescribed test equipment.

3. Strict compliance with Maintenance Instruction Manuals (MIM's) and Maintenance Requirement Cards (MRC's).

4. Conscientious observance of material handling/packaging requirements.

The VFA-125 MI policy states the procedures for cannibalizing parts from aircraft that are in SPINTAC status or out of readiness reporting. Permission from the wing is required. Prior to cannibalizing, the work center is required to perform thorough fault isolation, order a replacement part and turn in the unserviceable part. Maintenance/Material Control will determine if the supply status and part delivery time is adequate.

VMFAT-101's MI states many of the same themes of VFA-125's MI. The VMFAT-101 MI is combined with the SPINTAC instruction. In the discussion section it recognizes the increased man-hours incurred from cannibalization and the increased possibility of SPINTAC. It instructs the Maintenance Material control supervisor to interface with the supply department to minimize supply response times. It states that cannibalization should not be performed solely to avoid SPINTAC status. It instructs work center supervisors not to cannibalize without permission from Maintenance Control. As in the VFA-125 MI, cannibalization may only occur after the part is on order and the supply system has

had sufficient time to respond. The MI also states that cannibalization should not be used to improve FMC statistics.

If followed properly, the instructions presented above could prevent unnecessary cannibalizations. However, experience indicates procedures are not always followed when time is scarce and there is pressure to launch an aircraft. It is the responsibility of the Quality Assurance/Analysis Division to monitor cannibalization rates and trends. Often times the cannibalization numbers are recorded on the 3M summary, and then simply forgotten.

OPNAVINST 4790.2F states that when cannibalizations are managed properly it is a viable management tool. Policies should be flexible in nature. Both squadrons have very flexible MI's. Basically, it is up to the cognizant maintenance manager to select appropriate cannibalization opportunities. Without proper emphasis from the AMO, reiterating the principles in the cannibalization instructions, it would be easy to over use cannibalization as a quick fix to an immediate problem. The broader problems of supply response time, proper troubleshooting and lack of assets will not get the attention deserved.

IV. METHODOLOGY

A. INTERVIEWS

Although no formal interviews were conducted, several conversations with personnel from each of the squadrons and supporting commands provided valuable information on cannibalization and supply system policies and practices. At NAS Lemoore, the researchers spoke to squadron personnel in both Maintenance Control, the work centers, the data analyst, and the AMO. Topside representatives ranged from personnel in the Operations Department to the Commanding Officer. Information was also obtained from personnel in the Aviation Support Division.

For information on VMFAT-101, the researchers visited MALS-11, which is the squadron's supporting unit. MALS-11 provides intermediate maintenance and supply support for the squadron. Squadron personnel, to include the AMO and AAMO were also consulted for data and information.

B. DATA

There were two different uses for data. The data used in time-series analysis and linear regression was obtained from the squadron. Data was arranged in a spreadsheet to perform the necessary analysis. The data fields included the following for each month of the time period:

1. Cannibalization maintenance man-hours (Cann MMH)
2. Direct maintenance man-hours (DMMH)

3. Cannibalizations per 100 flight hours (Cann/100FH)

4. Flight hours (FH)

5. Mission capable rates (MC)

6. Sorties

7. Total number of cannibalizations (Total canns)

8. Direct maintenance man-hours per flight hour

Data for VFA-125 was taken directly from the 3M summaries, published by the squadron. Maintenance data for VMFAT-101 was obtained from the squadron. Flight information was extracted from the NAMO data base. BD/QQQ information was obtained from CNAP/NAVICP. Data used in analyzing the types and number of cannibalizations from 1994 through 1996 was extracted from the NALDA data base by COMNAVAIRPAC.

C. ANALYSIS

1. Time Series Plots

All data fields collected were plotted against time to identify any seasonal or cyclical patterns and to compare the squadrons against one another. Further analysis was performed on areas of interest.

2. Regression Analysis

Several variations of single and multiple regression analysis were performed to examine the linear relationship between cannibalizations and sorties, mission capability rates, direct maintenance man-hours, flight hours and cannibalization

maintenance man-hours. For each regression performed the regression parameters, their standard deviations as well as the t-ratios, p-values, R-squared and F statistic were calculated using the Minitab statistical program.

The general regression equation is $Y = b + m_1X_1 + m_2X_2 + \ldots m_kX_k$, where Y is the response variable and the X variables are the predictor variables. The constant b is the y-intercept. The m variables are the regression parameters/coefficients.

The t-ratio, p-values, R-squared and F statistic all help explain the relationship between the variables. All tests were performed at the 95 percent confidence level. The t-ratio is the ratio of the parameter estimates over their standard deviations. If the t-ratio is large enough for the applicable degrees of freedom, than there is a statistically significant linear relationship between the variables in the regression equation. The degrees of freedom for a t-distribution are derived by n-2 for simple regression and n-k-1 for multiple regression where n is the number of observations and k is the number of parameters. The values for the t-test were extracted from standard t-distribution tables.

The F statistic is related to and analyzed in the same manner as the t-ratio. In simple regression, it is the square of the t-ratio. In multiple regression the F test essentially combines the individual t tests into one test. It is a more reliable test in multiple regression because it is not affected

by colinearity.

The p-value is another indicator of the strength of the linear relationship between the variables in the equation. It is the probability of getting a value at least as extreme as the outcome observed. The smaller the p-value, the stronger the evidence of a significant relationship between variables. A p-value of less than .05 is considered strong evidence.

The correlation coefficients, R-squared and R-squared adjusted for degrees of freedom, are useful in analyzing the variability in the regression equation. The r-squared value is the percentage of the variability of Y that is explained by the variability in X. In multiple regression, the value is the percentage of variability in Y that is explained by the variability of the combination of the X variables.

3. Cost Analysis

To determine a cannibalization maintenance cost, $50 per maintenance man-hour was multiplied by the total number of cannibalization maintenance man-hours. The man-hours that were calculated are the man-hours required to remove and replace an item. These man-hours would not normally be required if the part was received from the supply system.

4. Failure Rate Analysis

NAVICP provided the original engineering estimates, and current Maintenance Replacement Factor (MRF) and Rotable Pool

Factor (RPF) for the twelve work unit code's representing the highest amount of cannibalizations for the two squadrons over the last three years.

V. DATA PRESENTATION

A. OVERVIEW

Table 5 is a broad look at the squadrons studied. The figures in the tables are the averages per month over the two year period for January 1995 to December 1996. Currently VFA-125 has 406 maintenance personnel and VMFAT-101 has 312. Both squadrons are assigned fewer personnel than they are authorized. They have both experienced personnel losses in the last few years.

	VFA-125	VMFAT-101
# Aircraft	41	32
Cann man-hours	688.8	479.1
Total man-hours	16,619.0	10,304.3
DMMH per FH	12.7	7.8
Canns per 100 FH	10.9	3.8
Flight Hours	1,329.7	1,330.3
Sorties completed	1053.4	1005.4
Mission capable rate	57.5	83.8

Table 5. Overview of Squadron Statistics

B. BASIC TRENDS

1. Cannibalizations

Cannibalizations are generally measured as the total number of items that were cannibalized per month, or as the number of cannibalizations per 100 flight hours for that month. Both of

these measures are considered here. Figure 1 illustrates the total number of cannibalizations per month for each of the two squadrons. Figure 2 shows the squadron comparison of cannibalizations per 100 flight hours. VFA-125 consistently reported a more cannibalizations. In both measures of cannibalization, there appears to be no cyclical or seasonal trend.

Probably the most important consideration when dealing with cannibalizations is the man-hours involved. Figures 3 and 4 compare cannibalization man-hours versus total maintenance man-hours for each squadron. The number on the top of each bar indicates the percentage of cannibalization man-hours. The percentage for VMFAT-101 ranges from one to 15 percent; while the range for VFA-125 is one to five percent. VMFAT-101 consistently reports fewer total man-hours than VFA-125.

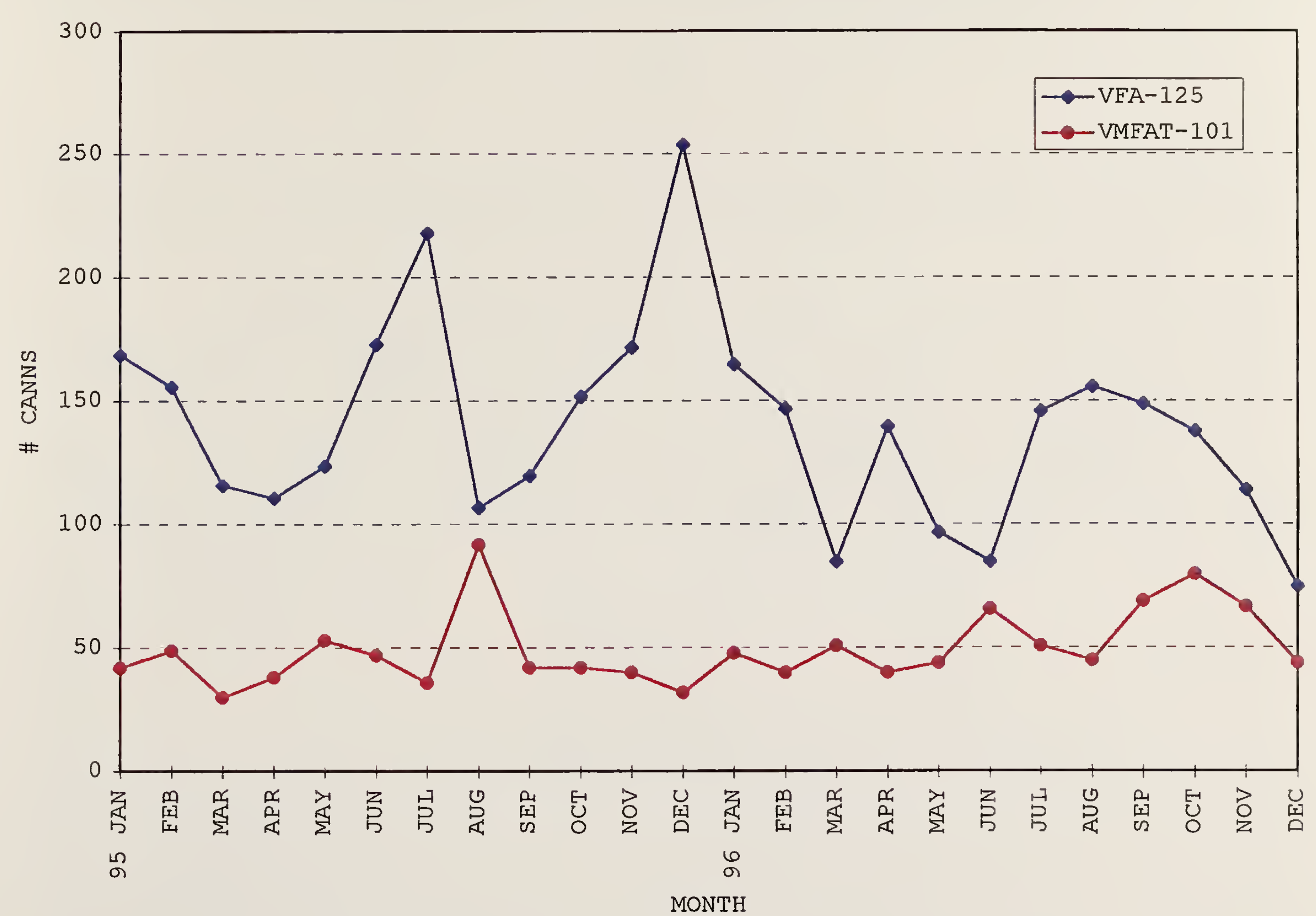

Figure 1. Total Number of Cannibalizations

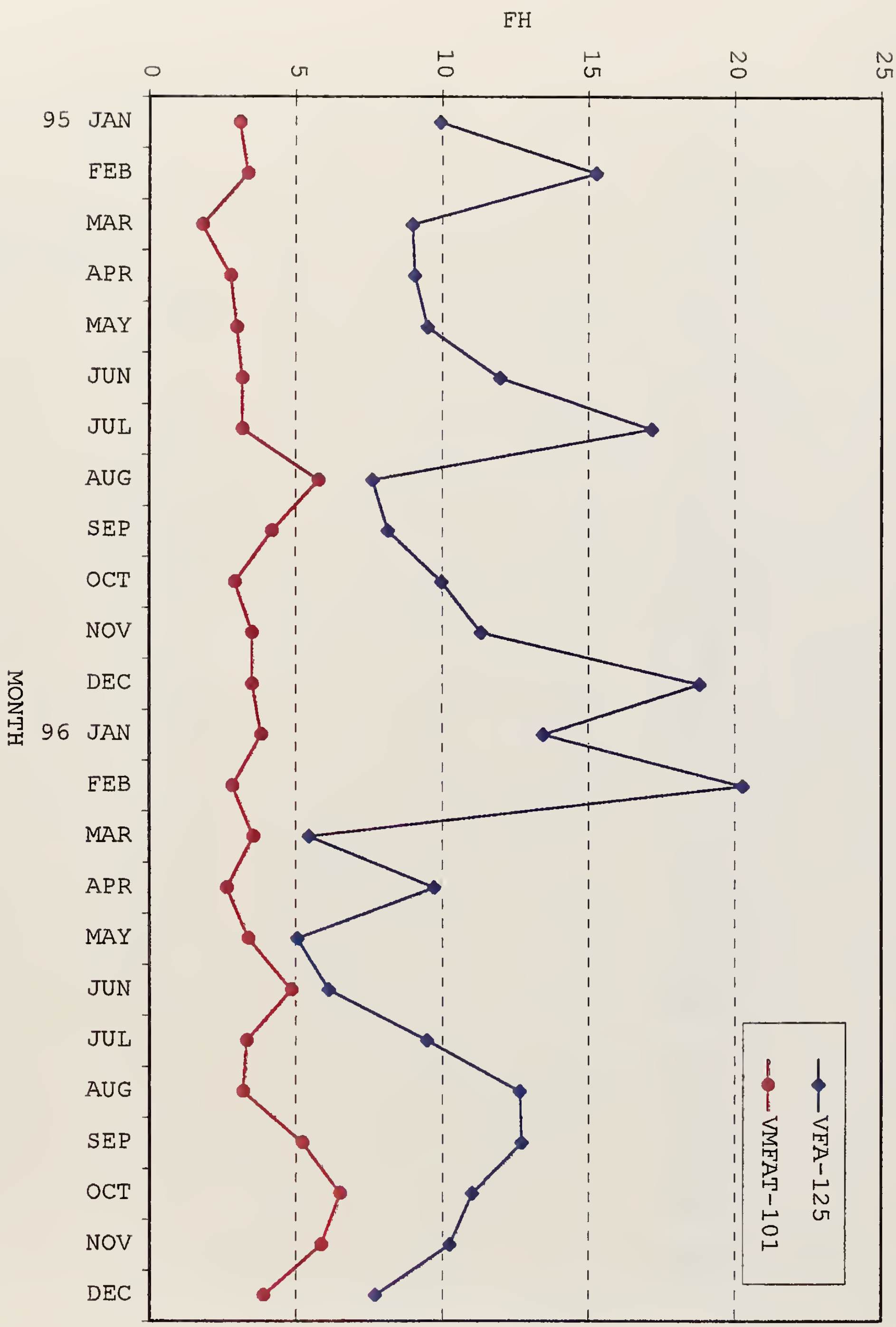

Figure 2. Cannibalizations per 100 Flight Hour

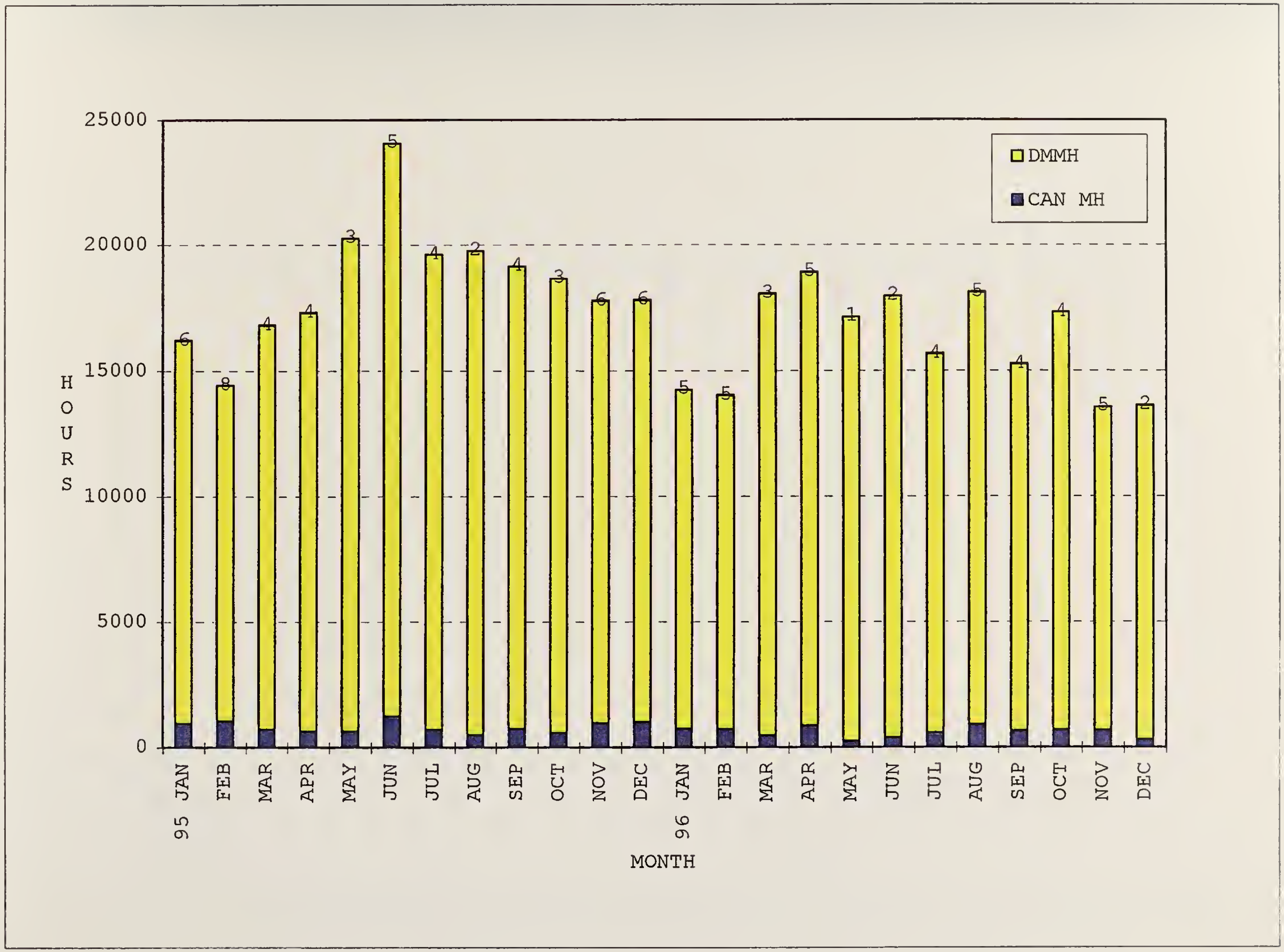

Figure 3. Cannibalization Man Hours vs. Total Maintenance Man Hours for VFA-125

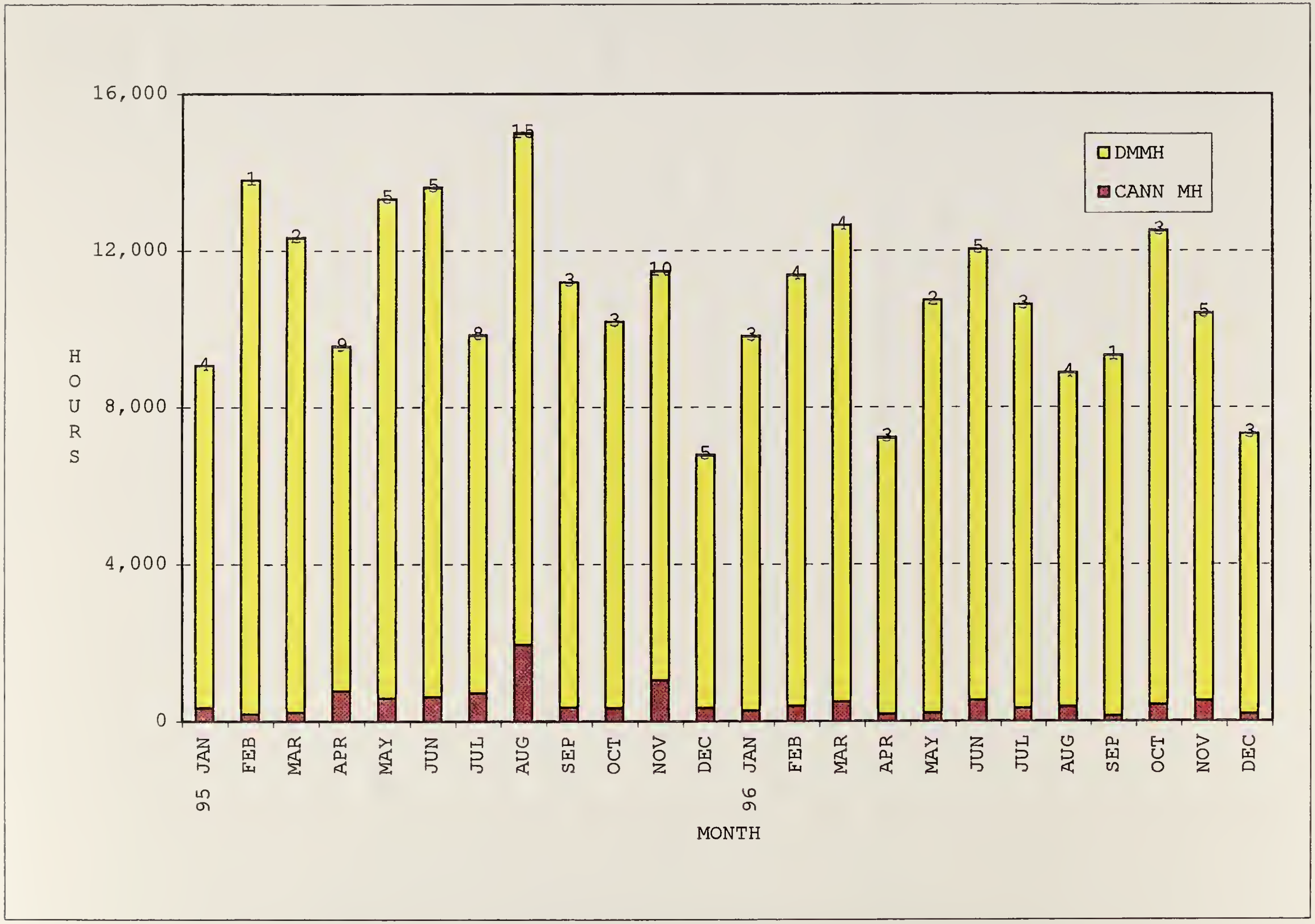

Figure 4. Cannibalization Man Hours vs. Total Maintenance Man Hours for VMFAT-101

2. Flight Operations

Flight operations are an important consideration when comparing cannibalizations. Figure 5a is a line representation of squadron flight hours. Figure 5b shows the same information in an area chart for easier volume comparisons. In some months the number of flight hours in each squadron is quite different, but the overall averages for the two year period are almost identical. The average for VFA-125 is 1329.7 hours and the average for VMFAT-101 is 1330.3 hours.

Figure 6a and 6b are similar to flight hour charts, but show sorties generation data. Sorties are similar for the two squadrons, except for the months of February and August. The averages are slightly different for the two year period. VFA-125 has an average of 1053.4 while VMFAT-101 has an average of 1005.4. The calculated average flight time for VFA-125 is 1.26 hours; it is slightly higher for VMFAT-101 at 1.32.

3. Mission Capable Rates

The mission capable rates for each squadron are displayed in Figure 7. The rates reported by VMFAT-101 are considerably higher than those of VFA-125. The two year average for VFA-125 is 57.5; and for VMFAT-101 it is 83.8.

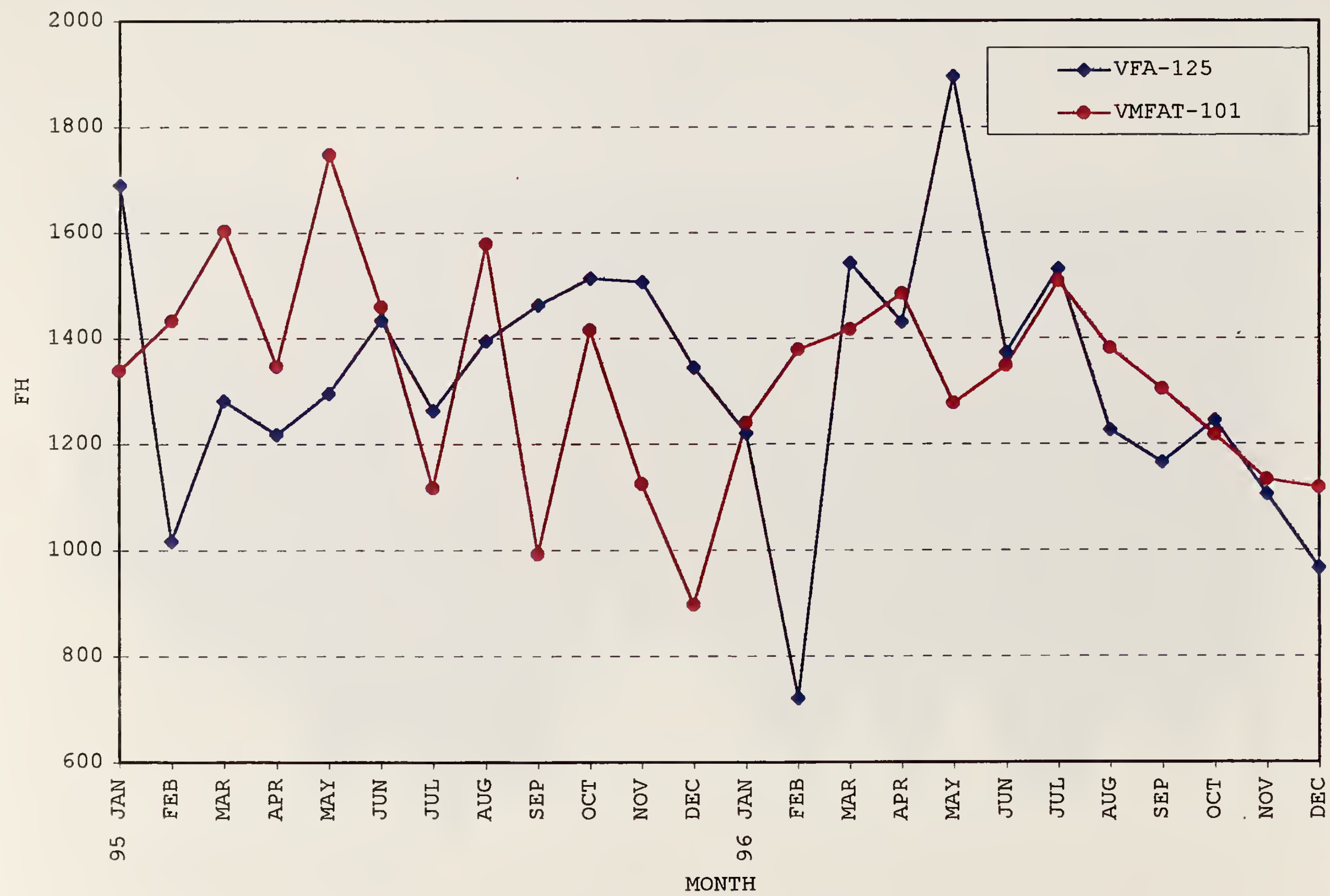

Figure 5a. Squadron Flight Hours

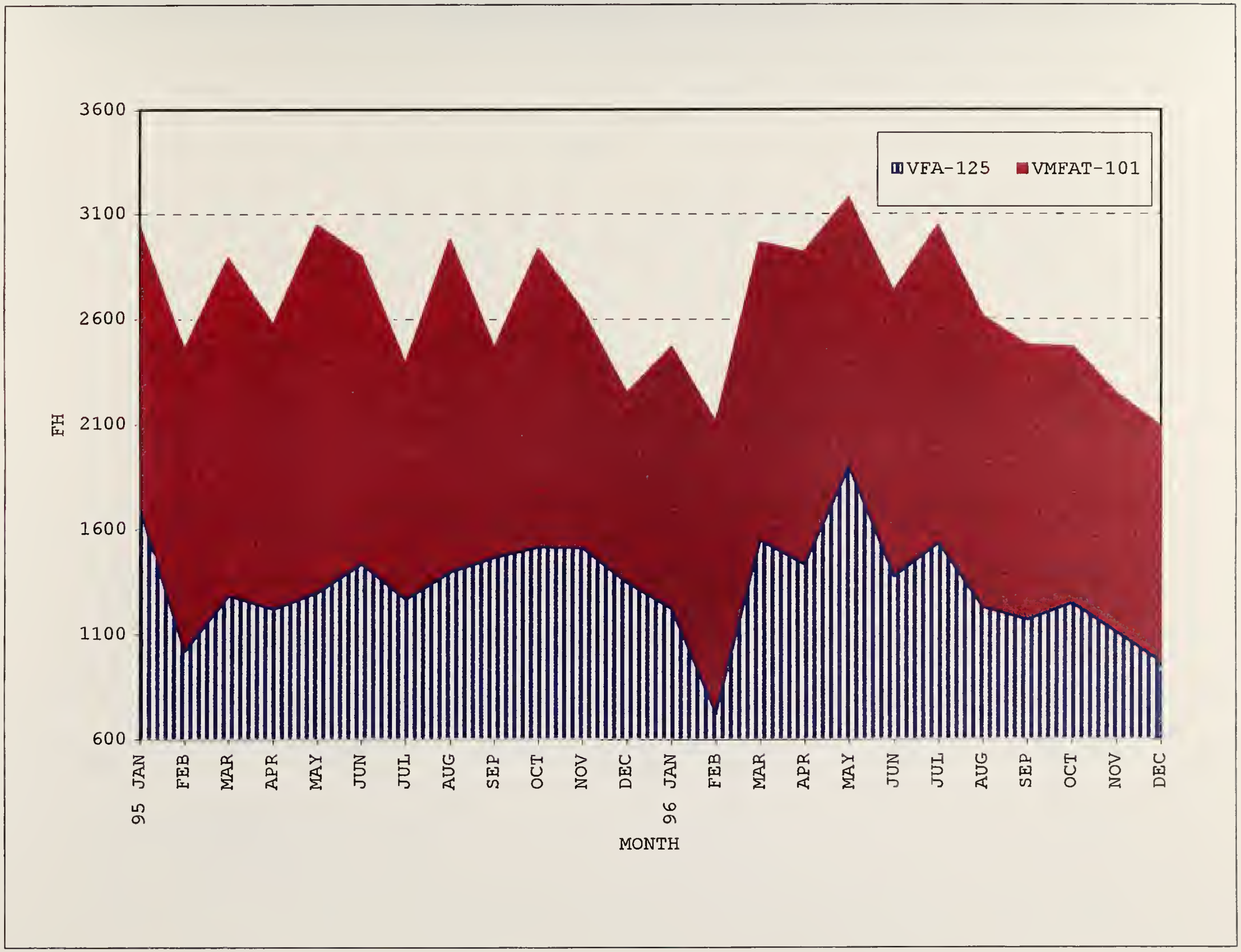

Figure 5b. Area Representation of Squadron Flight Hours

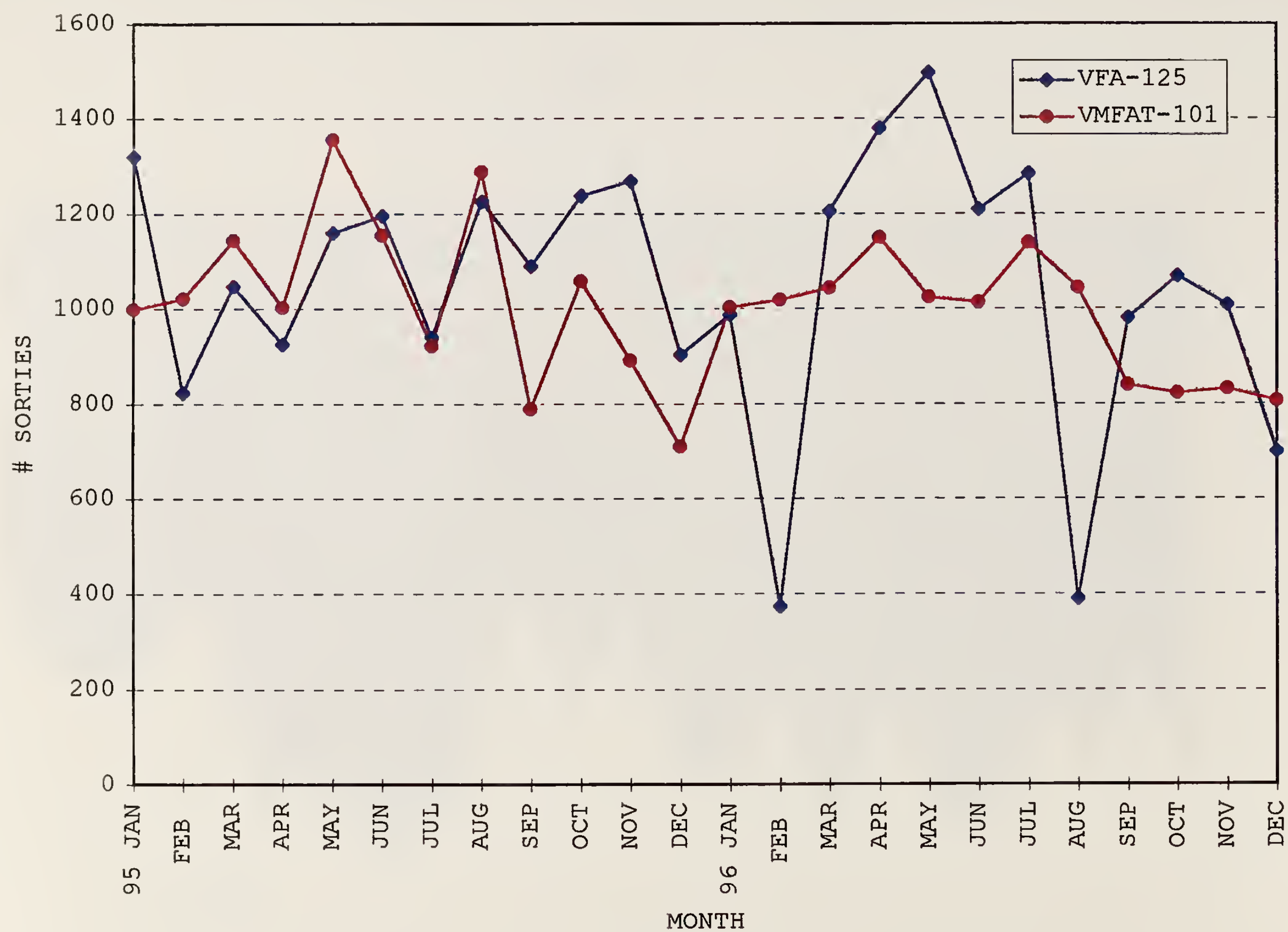

Figure 6a. Sorties Flown

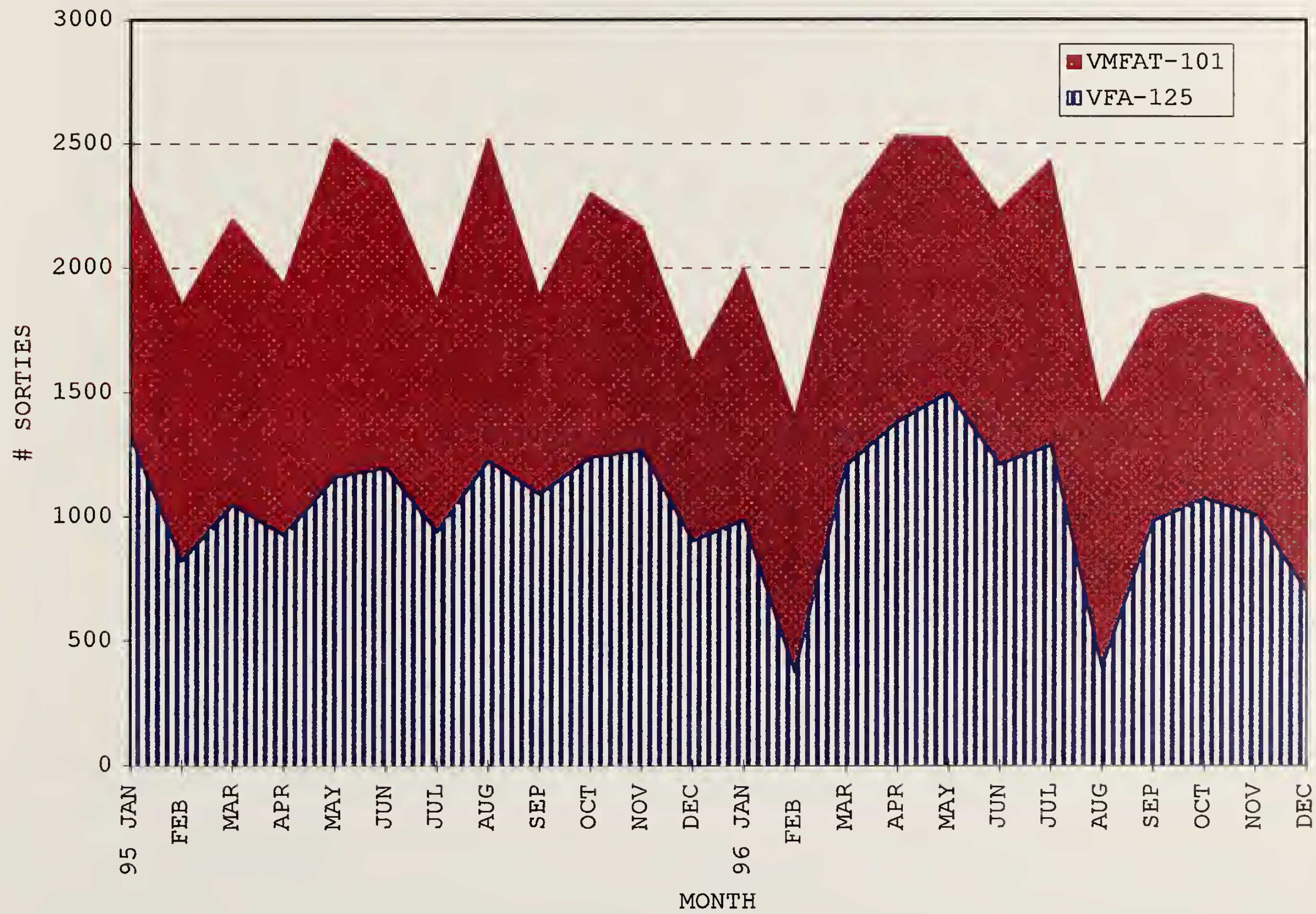

Figure 6b. Area Representation of Sorties Flown

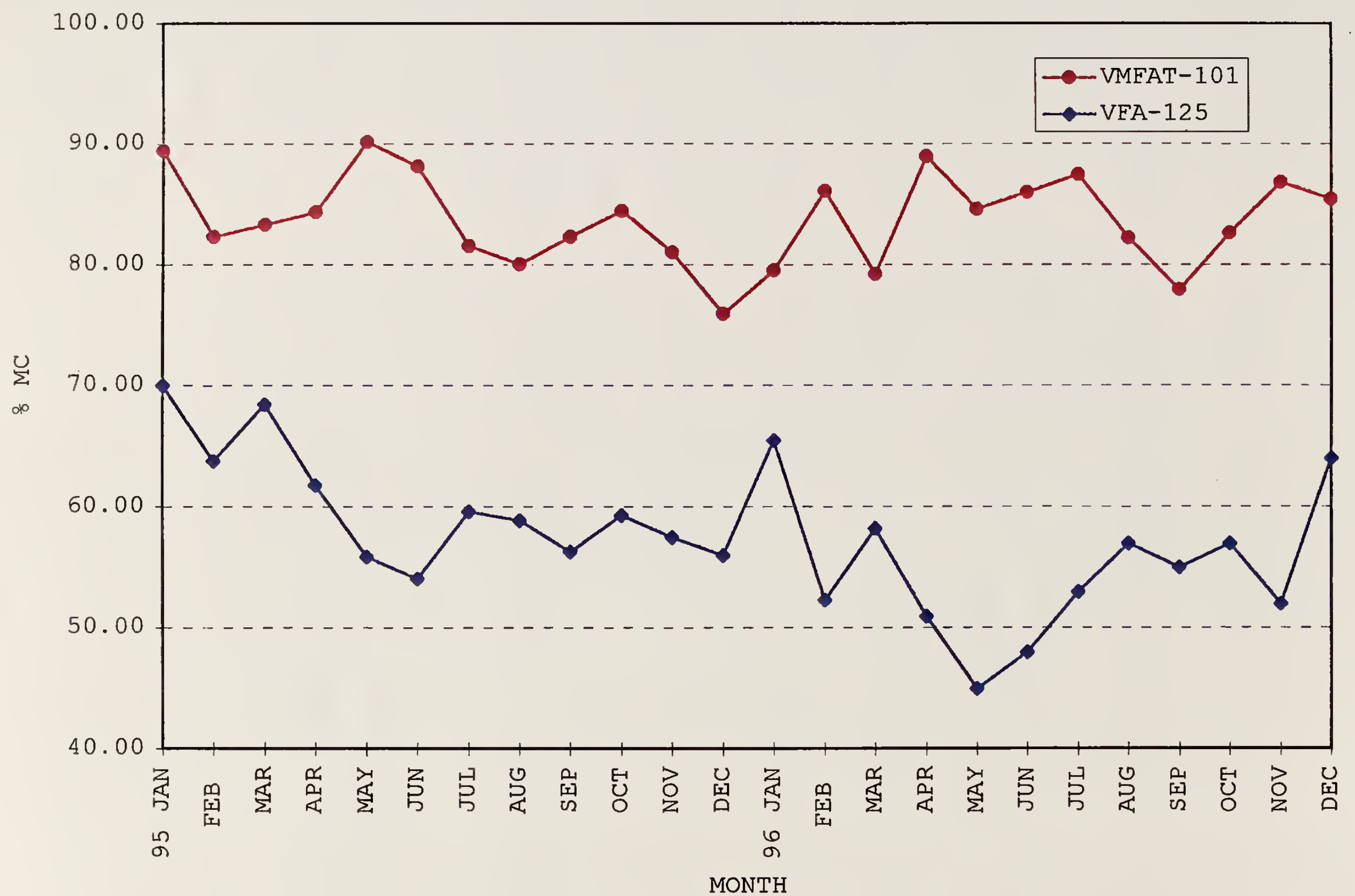

Figure 7. Squadron Mission Capable Rates

C. REGRESSION ANALYSIS

1. Correlation

The correlation between the variables in our study are shown in Table 6. The number in each box is the correlation coefficient of the two variables connected to that box. The highest correlation specifically related to cannibalizations was the correlation between cannibalizations per 100 flight hour and sorties flown for VMFAT-101 at -.615. This is a negative correlation, which means that if one goes up the other tends to go down.

VMFAT-101 \ VFA-125	Ttl Canns	FH	Sort Flwn	Cann /100 FH	Cann MMH	Ttl MMH	MC
Ttl Canns		-.018	-.161	.794	.705	.110	.144
FH	.190		.831	-.565	-.102	.483	-.172
Sort Flwn	.122	.933		-.615	-.172	.401	-.190
Cann/100	.876	-.291	-.348		.582	-.220	.111
Cann MMH	.464	.160	.331	.307		.175	.252
Ttl MMH	.421	.524	.491	.171	.337		-.232
MC	-.091	.456	.458	-.266	-.148	.095	

Table 6. Correlation Factors Between Variables

2. Linear Regression

Summaries of the regression results are presented in Figures 8 and 9. Columns represent the response variables and rows represent the predictor variables. The t-ratio for each coefficient is below the coefficient in parenthesis. More detailed outputs, including Analysis of Variance(ANOVA) tables are presented in Figures 10 through 29. The criteria for the t-ratio and F statistic for the regression equations was obtained from the distribution tables. A t-ratio greater than 1.717 and an F statistic greater than 4.3 are evidence of a linear relationship between the variables X and Y for the single regression equations. Only two regression equations met the criteria for the t-ratio, F statistic and p-value. They were both for VFA-125. The lines were cannibalizations per 100 flight hour as the independent variable and both sorties and cannibalizations maintenance man-hours as the dependent variables. The R-squared values for these lines were 37.1% for sorties and 33.9% for cannibalization maintenance man-hours.

The criteria for the F statistic for the multiple regression equations was 3.47 for two predictor variables and 3.10 for three predictor variables. For both squadrons, the regression equation with sorties as the response variable and cannibalizations per 100 flight hour and cannibalization maintenance man-hours as the predictor variables met the test criteria. The R-squared values

were 42.6% for VFA-125 and 33.4% for VMFAT-101. When the variable direct maintenance man-hours was added to the multiple regression equation, evidence of a relationship still existed and the R-squared values for both squadrons increased. The same predictor variables did not show strong evidence of a relationship with mission capable rates.

VFA-125	Constant	Sorties	MC	FH	Cann MMH	DMMH	R sq (%)	F	Fig #
Cann/100FH	1525.3 {-11.00}	-43.1 {-3.60}					37.1	13	8
Cann/100FH	55.609 {-14.61}		0.172 {.52}				1.2	0.27	10
Ttl Canns	1344.5 {7.31}			-0.11 {-.08}			0	0.01	12
Cann/100FH	301.1 {2.46}				35.4 {3.36}		33.9	11.3	14
Cann/100FH	18107 {12.15}					-135.9 {-1.06}	4.8	1.12	16
Cann MMH	15393 {9.93}					1.781 {.83}	3.1	0.7	18
VMFAT-101	Constant	Sorties	MC	FH	Cann MMH	DMMH	R sq (%)	F	Fig #
Cann/100FH	1188.8 {10.87}	-48.66 {-1.785}					12.2	3.06	9
Cann/100FH	87.129 {32.63}		-0.88 {-1.29}				7.1	1.67	11
Ttl Canns	1206.2 {8.46}			2.507 {.91}			3.6	0.83	13
Cann/100FH	91.3 {.34}				102.92 {1.51}		9.4	2.29	15
Cann/100FH	9186 {6.36}					296.9 {.81}	2.9	0.65	17
Cann MMH	9461.3 {14.89}					1.76 {1.68}	11.4	2.83	19

Figure 8. Summary of Simple Regressions

VFA-125	Constant	MC	Sorties	MC	Sorties	R sq (%)	F	Fig #
Cann/ 100 FH	53.44 {12.49}	-0.0831 {-.21}				6.5	0.73	22
Cann MMH		0.00721 {1.09}						
Cann/ 100 FH	1424.8 {9.30}		-54.93 {-3.82}			42.6	7.78	24
Cann MMH			0.3339 {1.41}					
Cann/ 100 FH	68.58 {6.65}			-3.559 {-.84}		17.2	1.38	26
Cann MMH				0.01143 {1.66}				
DMMH				-0.0009 {-1.60}				
Cann/ 100 FH	993.3 {2.63}				-47.16 {-3.04}	46.7	5.84	28
Cann MMH					0.2135 {.84}			
DMMH					0.02583 {1.25}			

VMFAT-101	Constant	MC	Sorties	MC	Sorties	R sq (%)	F	Fig #
Cann/ 100 FH	87.196 {31.90}	-0.8041 {-1.10}				7.6	0.86	23
Cann MMH		-0.0007 {-.33}						
Cann/ 100 FH	1170.44 {11.98}		-69.37 {-2.66}			33.4	5.27	25
Cann MMH			0.20126 {2.59}					
Cann/ 100 FH	84.073 {17.75}			-0.8482 {-1.15}		10.5	0.78	27
Cann MMH				-0.0013 {-.56}				
DMMH				0.00035 {.81}				
Cann/ 100 FH	833.7 {5.75}				-74.13 {-3.28}	52.7	7.43	29
Cann MMH					0.14005 {1.99}			
DMMH					0.03726 {2.85}			

Figure 9. Summary of Multiple Regressions

The regression equation is
Sorties = 1525 - 43.1 Cann/100FH

Predictor	Coef	Stdev	t-ratio	P
Constant	1525.3	138.7	11.00	0.000
Cann/100FH	-43.1	12.0	-3.60	0.002

s = 224.5   R-sq = 37.1%   R-sq(adj) = 34.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	P
Regression	1	654926	654926	12.99	0.002
Error	22	1109160	50416		
Total	23	1764086			

Figure 10. VFA-125 Regression Results. Sorties Flown: Cann/100FH

The regression equation is
Sorties = 1189 - 48.7 Cann/100FH

Predictor	Coef	Stdev	t-ratio	p
Constant	1188.8	109.4	10.87	0.000
Cann/100FH	-48.66	27.83	-1.75	0.094

s = 151.6   R-sq = 12.2%   R-sq(adj) = 8.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	70229	70229	3.06	0.094
Error	22	505644	22984		
Total	23	575874			

Figure 11. VMFAT-101 Regression Results. Sorties Flown: Cann/100FH

The regression equation is
MC = 55.6 +.172 Cann/100FH

Predictor	Coef	Stdev	t-ratio	p
Constant	55.609	3.806	14.61	0.000
Cann/100FH	0.172	0.328	0.52	0.605

s = 6.160 R-sq = 1.2% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	10.42	10.42	.27	0.605
Error	22	834.72	37.94		
Total	23	845.14			

Figure 12. VFA-125 Regression Results. MC: Cann/100FH

The regression equation is
MC = 87.1 - 0.879 Cann/100FH

Predictor	Coef	Stdev	t-ratio	p
Constant	87.129	2.671	32.63	0.000
Cann/100FH	-0.8790	0.6797	-1.29	0.209

s = 3.702 R-sq = 7.1% R-sq(adj) = 2.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	22.92	22.92	1.67	0.209
Error	22	301.55	13.71		
Total	23	324.47			

Figure 13. VMFAT-101 Regression Results. MC: Cann/100FH

The regression equation is
FH = 1344 - 0.11 Total Canns

Predictor	Coef	Stdev	t-ratio	p
Constant	1344.5	183.9	7.31	0.000
Total Canns	-0.106	1.259	-0.08	0.934

s = 250.0 R-sq = 0.0% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	439	439	0.01	0.934
Error	22	1374507	62478		
Total	23	1374946			

Figure 14. VFA-125 Regression Results. FH: Total Canns

The regression equation is
FH = 1206 + 2.51 Total Canns

Predictor	Coef	Stdev	t-ratio	p
Constant	1206.2	142.6	8.46	0.000
Total Canns	2.507	2.760	0.91	0.374

s = 199.8 R-sq = 3.6% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	32949	32949	0.83	0.374
Error	22	878479	39931		
Total	23	911428			

Figure 15. VMFAT-101 Regression Results. FH: Total Canns

The regression equation is
Cann MMH = 301 + 35.4 Cann/100 FH

Predictor	Coef	Stdev	t-ratio	p
Constant	301.1	122.2	2.46	0.022
Cann/100 FH	35.40	10.54	3.36	0.003

s = 197.9   R-sq = 33.9%   R-sq(adj) = 30.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	441561	441561	11.28	0.003
Error	22	861210	39146		
Total	23	1302770			

Figure 16. VFA-125 Regression Results. Cann MMH: Cann/100 FH

The regression equation is
Cann MMH = 91 + 103 Cann/100 FH

Predictor	Coef	Stdev	t-ratio	p
Constant	91.3	267.2	0.34	0.736
Cann/100 FH	102.92	68.01	1.51	0.144

s = 370.4   R-sq = 9.4%   R-sq(adj) = 5.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	314213	314213	2.29	0.144
Error	22	3019113	137232		
Total	23	3333325			

Figure 17. VMFAT-101 Regression Results. Cann MMH: Cann/100 FH

```
The regression equation is
DMMH = 18107 - 136 Cann/100 FH

Predictor        Coef        Stdev    t-ratio        p
Constant        18107         1490      12.15    0.000
Cann/100 FH    -135.9        128.5      -1.06    0.302

s = 2412        R-sq = 4.8%      R-sq(adj) = 0.5%

Analysis of Variance

SOURCE       DF          SS          MS          F        p
Regression    1     6511042     6511042       1.12    0.302
Error        22   128020464     5819112
Total        23   134531504
```

Figure 18. VFA-125 Regression Results. DMMH: Cann/100FH

```
The regression equation is
DMMH = 9186 + 297 Cann/100 FH

Predictor        Coef        Stdev    t-ratio        p
Constant         9186         1443       6.36    0.000
Cann/100 FH     296.9        367.4       0.81    0.428

s = 2001        R-sq = 2.9%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF          SS          MS          F        p
Regression    1     2614263     2614263       0.65    0.428
Error        22    88074344     4003379
Total        23    90688608
```

Figure 19. VMFAT-101 Regression Results. DMMH: Cann/100 FH

```
The regression equation is
DMMH = 15393 + 1.78 Cann MMH

Predictor         Coef        Stdev    t-ratio        p
Constant         15393         1551       9.93    0.000
Cann MMH         1.781        2.133       0.83    0.413

s = 2435          R-sq = 3.1%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS           MS          F         p
Regression      1      4132230      4132230       0.70     0.413
Error          22    130399272      5927240
Total          23    134531504
```

Figure 20. VFA-125 Regression Results. DMMH: Cann MMH

```
The regression equation is
DMMH = 9461 + 1.76 Cann MMH

Predictor         Coef        Stdev    t-ratio        p
Constant        9461.3        635.4      14.89    0.000
Cann MMH         1.760        1.047       1.68    0.107

s = 1911          R-sq = 11.4%     R-sq(adj) = 7.4%

Analysis of Variance

SOURCE         DF           SS           MS          F         p
Regression      1     10322412     10322412       2.83     0.107
Error          22     80366200      3653009
Total          23     90688608
```

Figure 21. VMFAT-101 Regression Results. DMMH: Cann MMH

The regression equation is
MC = 53.4 - 0.083 Cann/100 FH + 0.00721 Cann MMH

Predictor	Coef	Stdev	t-ratio	p
Constant	53.440	4.280	12.49	0.000
Cann/100 FH	-0.0831	0.4019	-0.21	0.838
Cann MMH	0.007205	0.006609	1.09	0.288

s = 6.133   R-sq = 6.5%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	55.13	27.56	0.73	0.492
Error	21	790.01	37.62		
Total	23	845.14			
Cann/100 FH	1	10.42			
Cann MMH	1	44.71			

Figure 22. VFA-125 Regression Results. MC: Cann/100 FH, Cann MMH

The regression equation is
MC = 87.2 - 0.804 Cann/100 FH - 0.00073 Cann MMH

Predictor	Coef	Stdev	t-ratio	p
Constant	87.196	2.733	31.90	0.000
Cann/100 FH	-0.8041	0.7291	-1.10	0.283
Cann MMH	-0.000728	0.002175	-0.33	0.741

s = 3.779   R-sq = 7.6%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	24.52	12.26	0.86	0.438
Error	21	299.95	14.28		
Total	23	324.47			
Cann/100 FH	1	22.92			
Cann MMH	1	1.60			

Figure 23. VMFAT-101 Regression Results. MC: Cann/100FH, Cann MMH

The regression equation is
Sorties Flown = 1425 - 54.9 Cann/100 FH + 0.334 Cann MMH

Predictor	Coef	Stdev	t-ratio	p
Constant	1424.8	153.3	9.30	0.000
Cann/100 FH	-54.93	14.39	-3.82	0.001
Cann MMH	0.3339	0.2367	1.41	0.173

s = 219.6 R-sq = 42.6% R-sq(adj) = 37.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	750956	375478	7.78	0.003
Error	21	1013130	48244		
Total	23	1764086			
Cann/100 FH	1	654926			
Cann MMH	1	96030			

Figure 24. VFA-125 Regression Results. Sorties: Cann/100FH, Cann MMH

The regression equation is
Sorties Flown = 1170 - 69.4 Cann/100 FH + 0.201 Cann MMH

Predictor	Coef	Stdev	t-ratio	p
Constant	1170.44	97.72	11.98	0.000
Cann/100 FH	-69.37	26.07	-2.66	0.015
Cann MMH	0.20126	0.07776	2.59	0.017

s = 135.1 R-sq = 33.4% R-sq(adj) = 27.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	192518	96259	5.27	0.014
Error	21	383356	18255		
Total	23	575874			
Cann/100 FH	1	70229			
Cann MMH	1	122289			

Figure 25. VMFAT-101 Regression Results. Sorties: Cann/100FH, Cann MMH

The regression equation is

MC = 68.6 - 0.356 Cann/100 FH + 0.0114 Cann MMH -0.000906 DMMH

Predictor	Coef	Stdev	t-ratio	p
Constant	68.58	10.32	6.65	0.000
Cann/100 FH	-0.3559	0.4235	-0.84	0.411
Cann MMH	0.011432	0.006900	1.66	0.113
DMMH	-0.0009065	0.000566	-1.60	0.125

s = 5.917 R-sq = 17.2% R-sq(adj) = 4.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	144.94	48.31	1.38	0.278
Error	20	700.20	35.01		
Total	23	845.14			
Cann/100 FH	1	10.42			
Cann MMH	1	44.71			
DMMH	1	89.81			

Figure 26. VFA-125 Regression Results. MC: Cann/100FH, Cann MMH, DMMH

The regression equation is

MC = 84.1 - 0.848 Cann/100 FH - 0.00130 Cann MMH +0.000346 DMMH

Predictor	Coef	Stdev	t-ratio	p
Constant	84.073	4.736	17.75	0.000
Cann/100 FH	-0.8482	0.7371	-1.15	0.263
Cann MMH	-0.001296	0.002302	-0.56	0.580
DMMH	0.0003456	0.0004262	0.81	0.427

s = 3.811 R-sq = 10.5% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	34.07	11.36	0.78	0.518
Error	20	290.40	14.52		
Total	23	324.47			
Cann/100 FH	1	22.92			
Cann MMH	1	1.60			
DMMH	1	9.54			

Figure 27. VMFAT-101 Regression Results. MC: Cann/100FH, Cann MMH, DMMH

```
The regression equation is
Sorties Flown = 993 - 47.2 Cann/100 FH + 0.213 Cann MMH + 0.0258
DMMH

Predictor         Coef          Stdev     t-ratio        p
Constant         993.3          378.0        2.63     0.016
Cann/100 FH     -47.16           15.52      -3.04     0.006
Cann MMH          0.2135          0.2529     0.84     0.409
DMMH              0.02583         0.02074    1.25     0.227
s = 216.8         R-sq = 46.7%       R-sq(adj) = 38.7%

Analysis of Variance
SOURCE          DF           SS            MS           F         p
Regression       3       823904        274635        5.84     0.005
Error           20       940181         47009
Total           23      1764086
Cann/100 FH      1       654926
Cann MMH         1        96030
DMMH             1        72948
```

Figure 28. VFA-125 Regression Results. Sorties: Cann/100FH, Cann MMH, DMMH

The regression equation is
Sorties Flown = 834 - 74.1 Cann/100 FH + 0.140 Cann MMH + 0.0373 DMMH

Predictor	Coef	Stdev	t-ratio	p
Constant	833.7	145.0	5.75	0.000
Cann/100 FH	-74.13	22.58	-3.28	0.004
Cann MMH	0.14005	0.07050	1.99	0.061
DMMH	0.03726	0.01305	2.85	0.010

s = 116.7 R-sq = 52.7% R-sq(adj) = 45.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	303495	101165	7.43	0.002
Error	20	272379	13619		
Total	23	575874			
Cann/100 FH	1	70229			
Cann MMH	1	122289			
DMMH	1	110977			

Figure 29. VMFAT-101 Regression Results. Sorties: Cann/100FH, Cann MMH, DMMH

D. ITEM ANALYSIS

1. Top Fourteen Items Cannibalized

The following analysis was done over a period of three years instead of two as in the previous analysis. The data was extracted from the Aviation 3M database. The top fourteen cannibalized items for both squadrons combined are presented in Table 7. The list was compiled by combining the top ten lists for each squadron.

WUC	NOMENCLATURE	1994		1995		1996	
		VMFAT 101	VFA 125	VMFAT 101	VFA 125	VMFAT 101	VFA 125
2740000	F404-GE engine	50	118	43	125	65	94
1461210	TE Flap hyd servo cylinder	23	51	46	113	46	74
742G100	T1377/APG65 radar transmitter	10	74	14	80	10	39
1431210	horiz stabilizer hyd servo cylinder	29	74	20	63	39	46
742G200	R2089/APG65 radar rxvr transmitter	10	61	12	53	9	43
742G600	AS3254/APG65 antenna	49	72	17	55	16	13
1421110	aileron	25	26	15	30	9	37
1441210	rudder hyd servo cylinder	2	33	4	53	10	20
1421210	ail activating hyd servo cylinder	5	29	6	28	6	36
57D9100	CP1330()/ASW44 roll pitch yaw	2	19	4	40	7	34
74D6100	AN/AVQ28 head-up display unit	27	20	20	28	12	20

7468100	IP1317/A digital display indicator	5	17	46	32	28	8
741P400	CP1699/AYK14 (v) digital data cr	16	27	18	13	4	7
62X2100	RT1250()/ARC radio receiver xmtr	13	4	13	2	8	0

Table 7. The Top Fourteen Items Cannibalized

Figures 30 and 31 illustrate the frequency of the top three cannibalized items for each squadron over a three year period. In each of the cases for VFA-125 cannibalizations peaked in 1995 and dropped in 1996. There was no significant pattern for the top three items for VMFAT-101.

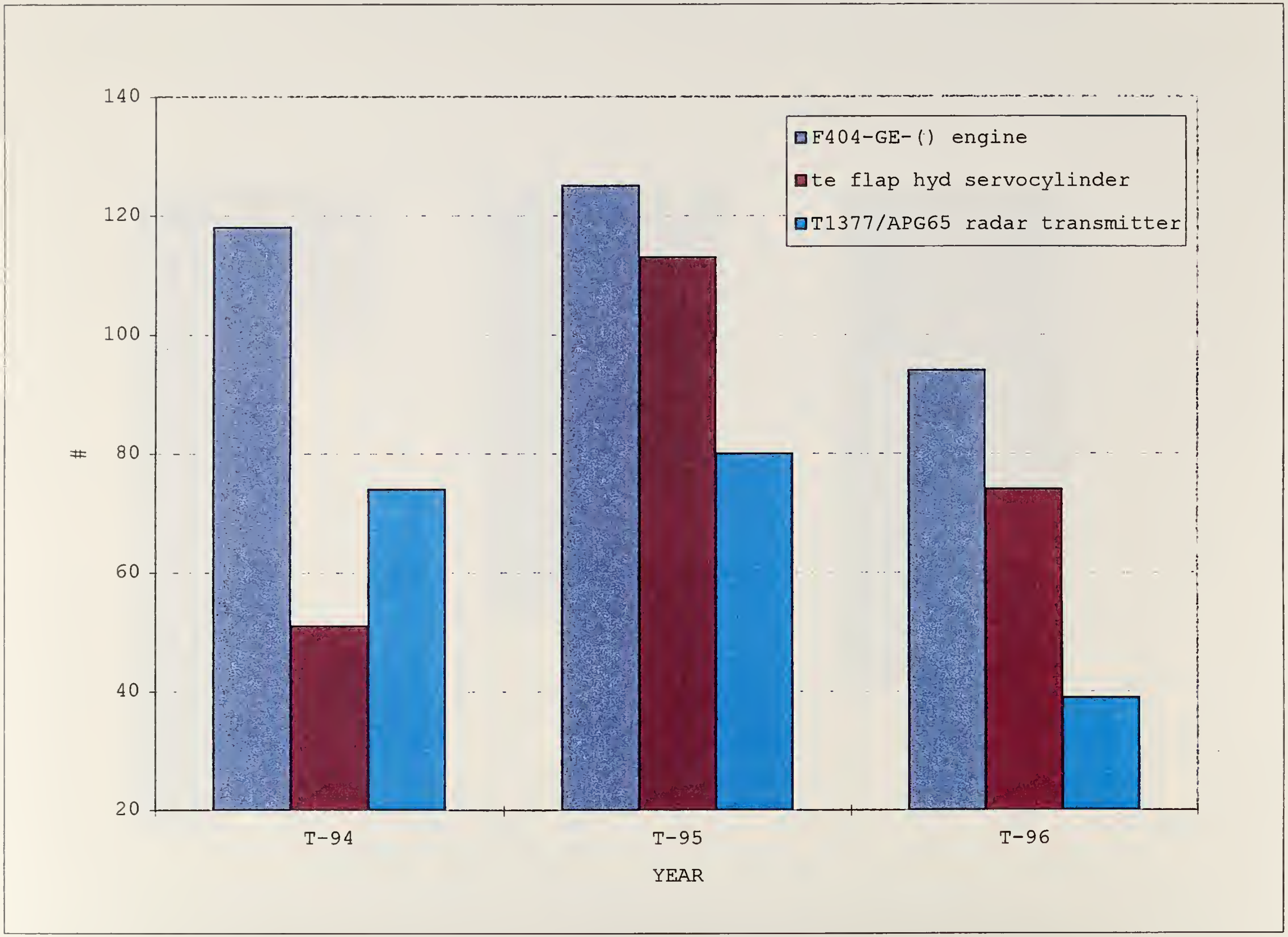

Figure 30. Top Three Cannibalized Items for VFA-125

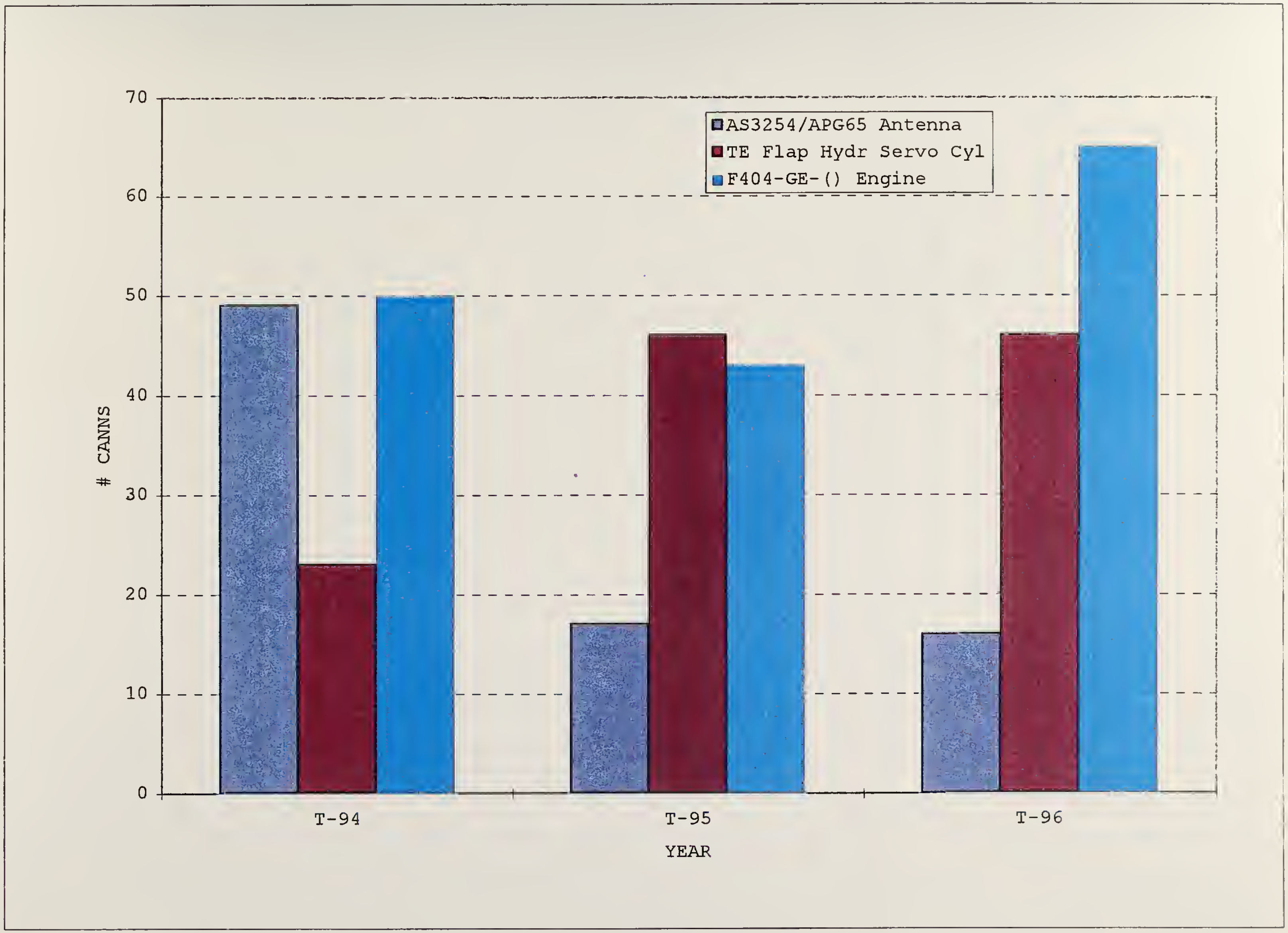

Figure 31. Top Three Cannibalized Items for VMFAT-101

2. Failure Rates

The failure rates for 12 of the top 14 cannibalized items are presented in Table 8. The original Maintenance Replacement Factor (MRF) is shown along with the original Rotable Pool Factor (RPF). Failure rates are calculated by adding the MRF and RPF. The current failure rate is compared to the previous failure and original failure rates to determine whether the rate is increasing or decreasing for those items.

WUC	Orig MRF	Orig RPF	Prev MRF	Prev RPF	Prev Fail Rate	Curr MRF	Curr RPF	Curr Fail Rate	Inc/ Dec
1421110	.009		.044	.037	.081	.048	.020	.068	Dec
1421210	.009	.035	.009	.043	.052	.003	.069	.072	Inc
1431210	.122		.060	.110	.170	.056	.137	.193	Inc
1441210	.027	.039	.027	.046	.073	.009	.077	.086	Inc
1461210	.005		.075	.105	.180	.043	.142	.185	Inc
57D9100	.026		.006	.238	.244	.009	.243	.256	Inc
741P400	.028		.006	.325	.331	.000	.383	.383	Inc
742G100	.010	.477	.009	.835	.844	.010	.617	.627	Inc
742G200	.010	.573	.011	.565	.576	.010	.569	.579	Dec
742G600	.004	.184	.013	.617	.630	.006	.390	.396	Inc
7468100	.023	.467	.023	.467	.490	.017	.516	.533	Inc
62X2100	.112		.002	.203	.205	.003	.239	.242	Inc

Table 8. Failure Rates for Highest Cannibalized Items.

E. MAN-HOUR COSTS

The cost of cannibalizations are reflected in the material costs of parts that are damaged or worn out prematurely due to frequent maintenance, and the man-hour costs of performing repetitive maintenance. Removing and replacing parts twice for cannibalization increases maintenance man-hours. The costs of the extra man-hours in each squadron are summarized in Table 9.

	VMFAT-101		VFA-125	
Month	FY95	FY96	FY95	FY96
Jan	$16,810	$13,650	$46,700	$36,300
Feb	9,385	19,415	51,350	35,100
Mar	11,050	24,730	35,105	23,200
Apr	38,250	8,860	30,720	42,050
May	29,095	10,660	30,635	11,650
June	31,685	27,000	61,105	18,250
July	35,880	16,485	34,445	27,800
Aug	97,085	18,510	23,700	44,650
Sept	17,350	6,725	35,850	32,200
Oct	17,055	20,700	27,850	34,400
Nov	52,605	25,970	47,350	32,750
Dec	16,910	9,030	49,065	14,100
Total	$373,160	$201,735	$473,875	$352,450

Table 9. Man Hour Costs of Cannibalization Per Month

F. DOCUMENTATION

There were many inconsistencies in the data collected. Data from VFA-125 3M Summary reports varied significantly from the

data in NALDA database at COMNAVAIRPAC. The variance between the two data sets is plotted in Figure 30. This data also differed from the data extracted from the cannibalization log book maintained by VFA-125. The patterns of the variance was random. There was no consistency in which source of information would produce the higher number. The data received from VMFAT-101 was very close to the data extracted form the database. Rounding errors could have caused the minor differences.

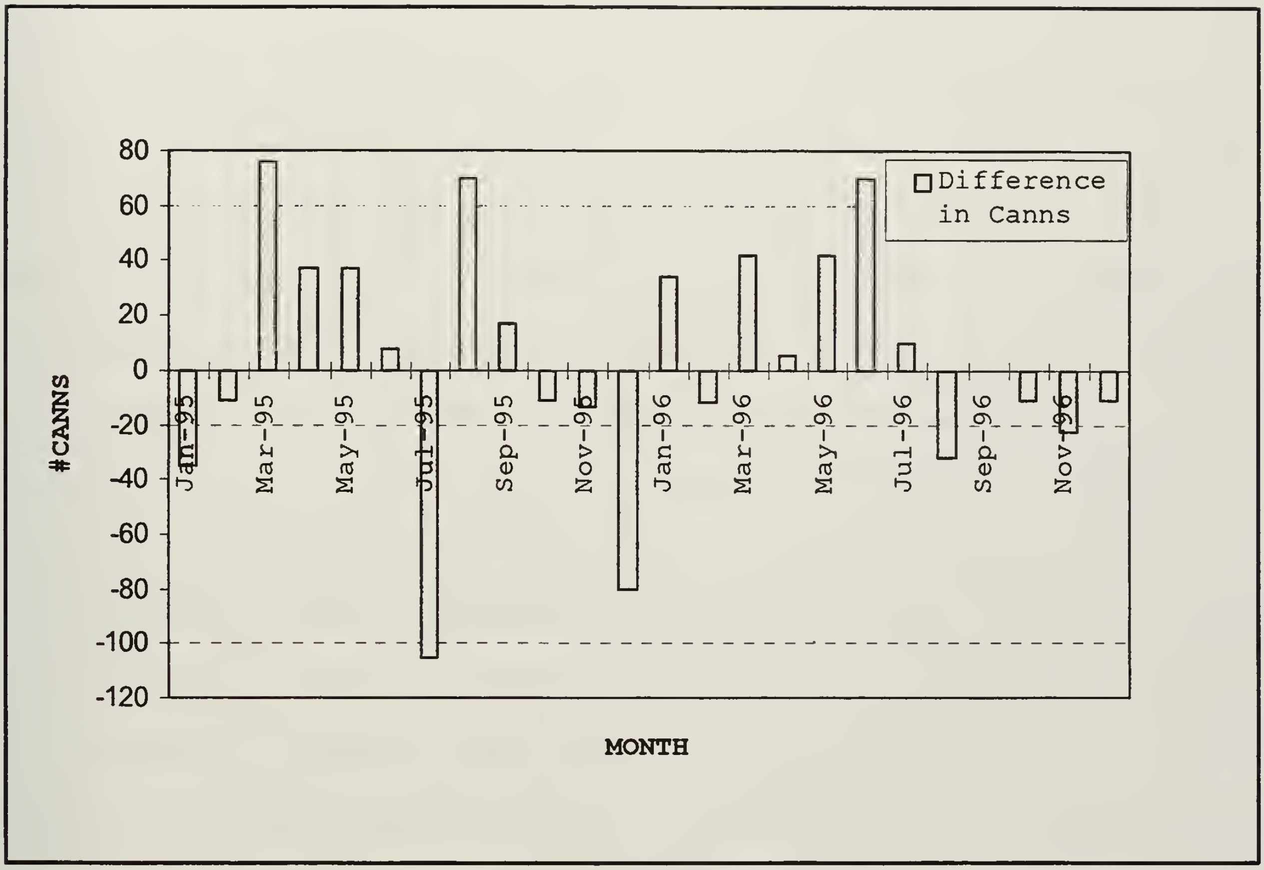

Figure 32. The Difference Between VFA-125 3M Summary Data and NALDA Data reported for the Number of Cannibalizations Per Month

VI. ANALYSIS OF DATA

A. DATA COMPARISON

1. Cannibalizations

The difference in flight hours per month per activity is statistically insignificant. Therefore, the cannibalizations per 100 flight hours reflect the same ratio as the cannibalization trend. The maintenance instructions for cannibalizations for each activity do not contain any significant differences that would explain the variation in cannibalizations between the squadrons. Interviews with the maintenance personnel at each facility did not explain the disparity in cannibalization occurrences. However, after reviewing the allowances at the two activities, VMFAT-101's supply support activity has markedly higher allowances for the high demand/frequently cannibalized items than does VFA-125. Higher allowances do not always mean more material is available. However, this notable difference between the two activities could explain the lower cannibalization percentage if material is on hand to support the allowances.

Although the total cannibalizations are much lower for VMFAT-101, the cannibalization man-hours as a percentage of total man-hours is generally higher than those of VFA-125. This presumably reflects the lower total man-hours reported by VMFAT-101. A difference in total man-hours is expected because of the difference in the number of personnel. However, the magnitude of

the difference is not proportional to the difference in personnel. An explanation for the large disparity is different documentation procedures. The documentation requirements are the same for both squadrons. However, in practice, the interpretations could be quite different.

There are inconsistencies in the data obtained from different sources for the same time period for each squadron. The cause of these discrepancies is largely unknown. Although the researchers did not investigate the data further, unprocessed or rejected AV3M data or creative reporting procedures within the organizations could lead to these inconsistencies.

2. Flight Hours/Sorties

As mentioned, flight hours between the activities are virtually the same. This suggests that the operations tempos at the two activities are relatively similar. Comparing the sorties provided similar results. Since the number of sorties is over 1000 per month, the difference is minor (less than 5%) and does not explain the difference in cannibalizations/maintenance requirements per month.

3. Mission Capability (MC) Rates

The difference in MC rates between the two squadrons is significant. One explanation of the higher MC rates for VMFAT-101 is that the aircraft in the squadron are reported in a mission capable status during scheduled maintenance. During

scheduled maintenance, the aircraft may require maintenance that in another situation would require the aircraft be reported not mission capable. Always reporting an aircraft mission capable during this type of maintenance could skew MC rates for the squadron. Research did not produce such a finding for VFA-125, which could explain the drastic difference in MC rates.

B. CORRELATION

The correlation coefficients in Table 6 produced interesting results. It was expected that sorties would increase flight hours; a strong positive correlation was anticipated. While total cannibalizations versus flight hours and total cannibalizations versus MC rate had low correlations, this does not discount the relationships. Cannibalizations are a minor part of the daily maintenance requirements, and their relational impact is actually several layers removed from the end product. For example:

MC = up time/total time

Up time = 1 - down time (DT)

DT = NMCS + NMCM + PMCS + PMCM.

Each of the sub components of DT involve various types of maintenance, including cannibalization requirements.

The correlation results display a myriad of relationships, positive and negative, weak and strong. Approximately 43% of the data for VFA-125 possesses greater than a 25% linear

relationship, while approximately 67% of the data for VMFAT-101 possesses greater than a 25% linear relationship.

C. LINEAR REGRESSION

Several versions of single and multiple regression analysis were performed on the data sets. Figure 8 shows that the linear relationships in the between the data are not very strong. The regression equation from VFA-125 indicated that cannibalizations per 100 flight hour have a negative impact on the number of sorties flown and a positive impact on cannibalization maintenance man-hours. 37.1% of the variability in sorties is described by the variability in cannibalizations per 100 flight hour. 33.9% of the variation in cannibalization maintenance man-hours is explained by the variability in cannibalizations per 100 flight hour.

The R-squared values for all of the regression equations are not very close to 100%. This means that there are other causes for the variation in the response variable besides the variation in the predictor variables used above. This is expected, because there are many factors that influence mission capability rates, flight hours, sorties, etc.... They include factors that are not maintenance related such as budget and flight hour allowances, personnel changes and differences in reporting procedures. Multiple regression analysis was used to explain more of the variability in sorties and mission capability.

The test criteria for all the different combinations of multiple regression on mission capability were not met. There is not significant evidence that cannibalizations per 100 flight hour combined with any of the other variables have a significant relationship with mission capability. This result is unexpected, since mission capability is a function of aircraft "up" time compared to "down" time. The various maintenance factors were expected to have a large impact on the mission capability rates. An explanation for the lack of a significant relationship is the flexibility afforded squadrons in reporting mission capable rates. If mission capability data is somewhat random, there would not be a strong relationship between the variables.

The multiple regression equations with sorties as the response variable produced the expected results. As more variables were added to the equation, the R-squared value increased. The additional predictor variables helped explain the variability in the response variable. Figures 24, 25, 28 and 29 show that a significant relationship exists between sorties and the combination of cannibalizations per 100 flight hour, cannibalization maintenance man-hours and direct maintenance man-hours. Cannibalizations per 100 flight hour has a negative relationship with sorties. Cannibalization maintenance man-hours and direct maintenance man-hours have a positive relationship with sorties flown.

D. FAILURE RATE ANALYSIS

In Table 8, where failure rates are listed, in the cases where the original RPF was unavailable, the previous failure rate was compared with the current failure rate. Where original MRF and RPF was available, the original estimate was compared to the previous and current failure rates to determine if the item's failure rate was increasing or decreasing.

In all but two cases, failure rates are increasing (though in two of the increasing cases there is a decrease between the previous and current failure rates). This means that the components are failing more frequently than estimated. Nine of these items have not only increased from original estimates, but have continued to increase over previously calculated failure rates. These components represent twelve of the fourteen highest cannibalized items at the Pacific Fleet FRS's. Data for the remaining two items were not available.

E. CANNIBALIZATION COSTS

Table 9 displays the financial impact associated with cannibalizations. Since a cannibalization maintenance action would not normally be performed if the material was readily available, these are additional maintenance costs that are absorbed in the normal maintenance budget.

VFA-125 expended $826,325 due to cannibalization maintenance man-hours while VMFAT-101 expended $574,895 for cannibalization

maintenance man-hours over the same two year period. These figures are labor cost and do not include the additional parts and material cost. The man-hours used in cannibalization are duplicate man-hours. The part must be removed and replaced twice by the time the cannibalized aircraft is restored. In the current atmosphere of down-sizing and budget shortages this is a large source of waste.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. OBJECTIVES

This thesis analyzed cannibalization as it effects the Pacific Fleet Navy and Marine Corps F/A-18 Fleet Replacement Squadrons. The objectives of this thesis were to research the F/A-18 supply/support posture, compare two squadrons, analyze the number and type of canns performed, determine if cannibalization is a useful practice and identify if significant shortages exist in the supply support system.

B. CONCLUSIONS

The following are the conclusions of this research:

1. Shortages in the supply system and slow supply response times are a major cause of cannibalizations.

2. An increase in cannibalizations causes an increase in component failure rates.

3. Cannibalization causes repetitive maintenance and it has a high opportunity cost. It depletes resources used for other maintenance/activities.

4. An increase in cannibalizations per 100 flight hours has a negative impact on sorties completed.

5. The research did not find a significant linear relationship between cannibalizations and mission capable rate, flight hours completed, and direct maintenance man-hours.

6. There were many inconsistencies between the different data sources.

7. The reliance on manual tracking systems is inadequate in capturing cannibalization data.

8. There is a difference in the maintenance practices and reporting policies between the squadrons.

C. RECOMMENDATIONS

The following are recommendations from this research:

1. Improvements are needed in the aviation supply system. Material requirements need 100% funding. The buy-in/buy-out process needs to be condensed to meet material requirements more rapidly. Initial outfitting documents need to be funded and filled more expeditiously.

2. Cannibalizations should be minimized and only used to meet critical mission requirements. Cannibalizations should not be used to avoid SPINTAC situations nor to increase readiness.

3. A better tracking system is needed to capture cannibalization data. Manual tracking systems for cannibalizations are redundant and should be eliminated to avoid documentation disparities.

4. Incentives should be incorporated to encourage accurate maintenance reporting. During assist visits from wing and type commanders squadron records should be audited and compared against actual practices. The results should be part of the

criteria for squadron awards and individual evaluations instead of mission capability rates.

5. More specific guidance is needed for cannibalization. A checklist including time lines and situations warranting cannibalization actions should be included in Squadron MI's.

6. There should be one data source that historically archives all Aviation Maintenance 3M data providing the same information to all who extract the data. The current NALDA database does not perform this function adequately. The cannibalization trends in this database should automatically prompt inventory management activities to update failure rates and make necessary procurement adjustments.

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